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Tornado Protection

Selecting Refuge Areas in Buildings

FEMA

Florida Department of Community Affairs
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About the Cover

The large photograph on the cover shows the remains of a central corridor in the Kelly Elementary School, in Moore, Oklahoma. This extensive damage was caused by one of the tornadoes that struck Oklahoma and Kansas on May 3, 1999. The corridor walls, which consisted of lightweight steel frame members with masonry infill topped by clerestory windows, were unable to withstand the extreme loads caused by lateral and uplift wind forces. As indicated by the inset photograph, which shows a similar corridor in another school, this type of corridor construction is common and creates special challenges for building administrators and design professionals who must identify refuge areas in schools and other buildings.

Contents

Foreword

Tornadoes cause heavy loss of life and property damage throughout much of the United States. Most schools and other public buildings include areas that offer some protection from this danger, and building administrators should know the locations of these areas.

This booklet presents case studies of three schools that were struck by tornadoes: Xenia Senior High School in Xenia, Ohio; St. Augustine Elementary School in Kalamazoo, Michigan; and Kelly Elementary School in Moore, Oklahoma, which were struck on April 3, 1974; May 13, 1980; and May 3, 1999, respectively. The resulting damage to these schools was examined by teams of structural engineers, building scientists, engineering and architectural faculties, building administrators, and representatives of the architectural firms that designed the buildings. From these and other examinations, guidance has been developed for selecting the safest areas in existing buildings – areas that may offer protection if a tornado strikes – referred to in this booklet as the *best available refuge areas*.

The guidance presented in this booklet is intended primarily to help building administrators, architects, and engineers select the best available refuge areas in existing schools. Building administrators, architects, and engineers are encouraged to apply this guidance so that the number of injuries and deaths will be minimized if a tornado strikes an occupied school.

For the design of shelters in schools yet to be constructed, refer to FEMA publication 361, *Design and Construction of Community Shelters*.

Introduction

What Are "Best Available Refuge Areas"?

The term ***best available refuge areas*** refers to areas in an existing building that have been deemed by a qualified architect or engineer to likely offer the greatest safety for building occupants during a tornado. It is important to note that, because these areas were not specifically designed as tornado shelters, their occupants may be injured or killed during a tornado. However, people in the best available refuge areas are less likely to be injured or killed than people in other areas of a building.

The likelihood that a tornado will strike a building is a matter of probability. Tornado damage to buildings is predictable. Administrators of schools and other public buildings should have a risk analysis performed to determine the likelihood that a tornado will occur and the potential severity of the event. If a building is determined to be at sufficient risk, the safest areas of the building – areas that may offer protection if a tornado strikes – should be identified. This booklet refers to such areas as the ***best available refuge areas***. In many buildings, the best available refuge areas are large enough to accommodate the number of people who normally occupy the building. A qualified architect or structural engineer should assess an existing building and identify the best available refuge areas.

This booklet presents information that will aid qualified architects and engineers in the identification of the best available refuge areas in existing buildings. Architects and engineers who are designing tornado shelters within new buildings may also find this booklet useful, but should refer to *Design and Construction Guidance for Community Shelters* (FEMA 361) for more detailed information. FEMA 361 includes design criteria, information about the performance of specific construction materials under wind and debris impact loads, and examples of construction plans and costs.

The Wind Engineering Research Center at Texas Tech University provided much of the substance of this booklet. Dr. Kishor Mehta of the Center assisted in the preparation and review of the material. Invaluable assistance was provided by the architects and engineers of the buildings presented as case studies and by the school administrators.